DOCUMENT RESUME

ED 449 021 SE 064 383

AUTHOR	Holzer, Siegfried M.; Andruet, Raul H.
TITLE	Learning about Trusses with Multimedia.
SPONS AGENCY	National Science Foundation, Arlington, VA.
PUB DATE	1998-00-00
NOTE	14p.; Paper presented at the Annual Meeting of the International Conference on Engineering Education (Rio de Janeiro, Brazil, August 17-20, 1998). Figures may not reproduce well. Funding given to SUCCEED, a coalition of eight schools and colleges working ot enhance engineering education.
CONTRACT	EID-9109053
PUB TYPE	Reports - Descriptive (141) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Building Design; *Engineering Education; Higher Education; Mechanics (Physics); *Multimedia Materials; Prefabrication; Science Activities; Science Instruction

ABSTRACT

The researchers are developing a learning environment in the subject area of statics that includes physical models, interactive multimedia, traditional pencil-and-paper activities, and cooperative learning in the framework of experiential learning (Kolb, 1984). They are using Authorware Professional to construct the multimedia program. The researchers taught a section of statics in this format, which now includes topics from mechanics of materials, for the third time in the fall of 1997 to students in architecture. This paper describes briefly the learning environment (Holzer and Andruet, 1998) and illustrates how students are guided to learn about trusses. Twenty-three figures from the multimedia program make up the majority of the document. (Author/SAH)

Reproductions supplied by EDRS are the best that can be made
from the original document.

S. Holzer

Learning about Trusses with Multimedia

Siegfried M. Holzer and Raul H. Andruet
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061
holzer@vt.edu

U.S. DEPARTMENT OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.
Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

ED 449 021

Abstract - *We are developing a learning environment in the subject area of statics that includes physical models, interactive multimedia, traditional pencil-and-paper activities, and cooperative learning in the framework of experiential learning (Kolb, 1984). We are using Authorware Professional to construct the multimedia program. We taught a section of statics in this format, which now includes topics from mechanics of materials, for the third time in the fall of '97 to students in architecture. In this paper we describe briefly the learning environment (Holzer and Andruet, 1998) and illustrate how students are guided to learn about trusses.*

Learning Environment

> *Learning is the process whereby knowledge is created through the transformation of experience.*
> **David Kolb** (1984)

Experiential learning focuses on the two fundamental activities of learning: grasping and transforming experience (Fig. 1). Each activity involves two opposite but complementary modes of learning. One can grasp an experience directly through the senses (sensory, inductive mode) or indirectly in symbolic form (conceptual, deductive mode). Similarly, there are two distinct ways to transform experience, by reflection or action. At any moment in the learning process, one or a combination of the four fundamental learning modes may be involved. It is significant that their synthesis leads to higher levels of learning (Kolb, 1984). This is confirmed in a study by Stice (1987), which shows that the students' retention of knowledge increases from 20% when only abstract conceptualization is involved to 90% when students are engaged in all four stages of learning.

Our class meets in a computer lab where two students share one computer. This facilitates cooperative learning where the pair is the basic unit.

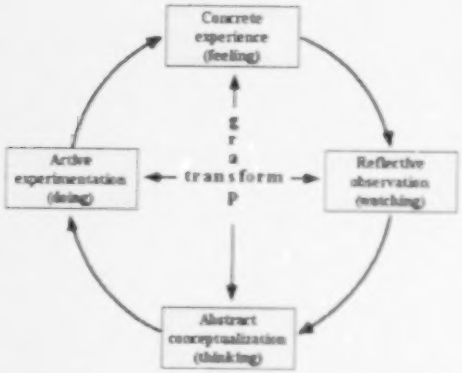

Figure 1. Experiential Learning Model (Kolb, 1984, p. 42)

Examples of cooperative learning structures for pairs include think-pair-share (**TPS**) (Lyman, 1987) and think-aloud-pair-problem-solving (**TAPPS**) (Lochhead, 1987). We found that in the classroom environment, teams of two students are more effective than teams of three or more students because the one-on-one interaction of a pair can accommodate students with diverse characteristics. In groups of three or more students, one student is frequently left out. For example in **TAPPS**, where one student is the problem solver and the other the listener, the roles of the members are so well defined that cooperation is necessary. Once students have become experienced with **TAPPS**, they may prefer a more flexible version that permits collaboration during the solution process. This was recommended by students experienced in **TPS**; now we use a modified version which we call **MTAPPS**.

Learning about Trusses

We learn about trusses by identifying their characteristics, constructing mathematical models, and analyzing models of trusses (Fig. 2). The analysis of trusses (Fig. 3) is divided into **member forces**, to develop concepts of two- and three-force members (Holzer and Andruet, 1998), **methods of analysis**, which includes their development (inductive) and summary (deductive), and the solution of **problems**.

BEST COPY AVAILABLE

ED 449 021

Method of Sections

Here we illustrate the development of the method of sections and its application in the solution of two truss problems.

Development

The objective is to learn how we can use sections of trusses to compute member forces. A section is an isolated part of a truss containing two or more joints. The development of the method of sections involves the first three stages of experiental learning (Fig. 1). Effective activities for the first stage are hands-on laboratory experiments that engage students directly through concrete experiences. Specifically, students may be asked to guess whether a member is in tension or compression and to measure member forces. It is simple to measure tensile forces with spring scales (Fig. 4), but it is not obvious how to measure compressive forces. This provides the opportunity for posing a puzzler, a very effective way to stimulate interest and involvement: how can we measure a compressive member force with a spring scale that records tension? Students are asked to work cooperatively in pairs to answer the question. The benefit of such experiences is the active involvement in learning and the process of discovering new concepts. The answer to the question is illustrated in Fig. 5. We use such experiments in a hands-on-statics laboratory, a pilot course supported by SUCCEED. Our goal is to promote the integration of elements from this pilot course in the standard engineering statics course.

Figures 4, 6, and 7 are concerned with the **analysis** (reflective observation) of the experiment and the formulation of an analysis **procedure** (abstract conceptualization) based on truss sections. We found that traditional pencil-and-paper activities (Manual in Fig. 4) facilitate learning with multi-media tools. Analysis results are displayed in Fig. 6. It is difficult for some students to realize that the member forces acting on one section represent the effect of the other section, the portion of the truss removed, and that free-body-diagrams are virtual concepts. The product of this development, the method of sections, is summarized and illustrated in Fig. 7.

Analysis of a simple truss

Figures 8-16 illustrate activities in the analysis of a simple truss that are inquiry-based to promote cooperative learning. The objective is to compute each member force directly from a single condition of equilibrium (Fig. 8.). The analysis process includes choices and questions. For example, one can select the member force (Fig. 9), the method of analysis (Fig. 10), and the condition of equilibrium (Fig. 14). Questions concern the choice of a section (Fig. 12), the assumed sense of a force (Fig. 13), and the equilibrium of the final FBDs of the sections (Fig. 16), which are constructed by the students. Figure 11 shows the integration of pencil-and-paper with multimedia activities. Figures 14 and 15 illustrate constructive feedback: generally, the program provides a clue in response to the first error in a small task and the solution after the second error.

Analysis of a complex truss

One objective of the problem in Fig. 17 is to compute the force in member 4 with the fewest conditions of equilibrium. The solution procedure is first discussed by students in teams (**TPS**). This is followed by a class discussion based on the solution in Figs. 18 and 19. The FBD for the computation of F_1 and feedback to the second error are displayed in Fig. 20. After the computation of F_4, students are asked to identify the zero-force members. Feedback in Fig. 21 guides this task. Finally, the students are asked to compute the remaining member forces (Fig. 22) and color code the result (Fig. 23).

References

Holzer, S. M. and R. H. Andruet, "Students Developing Concepts in Statics," *1998 ASEE Annual Conference and Exposition*, Seattle Washington, June 28 – July 1 (1998)

Holzer, S. M. and R. H. Andruet, "Learning Statics with Multimedia and Other Tools," *1998 ASEE Annual Conference and Exposition*, Seattle Washington, June 28 – July 1 (1998)

Kolb, D., *Experiential Learning*, Prentice Hall, Englewood Cliffs, NJ (1984)

Lochhead, J., "Teaching Analytical Reasoning Through Thinking Aloud Pair Problem Solving," in James E. Stice, Ed., *Teaching Thinking Through Problem Solving*, New Directions for Teaching and Learning, No. 30, Jossey-Bass, San Francisco (1987)

Lyman, F., "Think-Pair-Share: An Expanding Teaching Technique," MAACIE, *Cooperative News*, 1(1) (1987)

Stice, J. E., "Using Kolb's Learning Cycle to Improve Student Learning," *Engineering Education*, 77 (5), February (1987)

Acknowledgment

Funding for this work was provided by the NSF to SUCCEED (Cooperative Agreement No. EID-9109053).

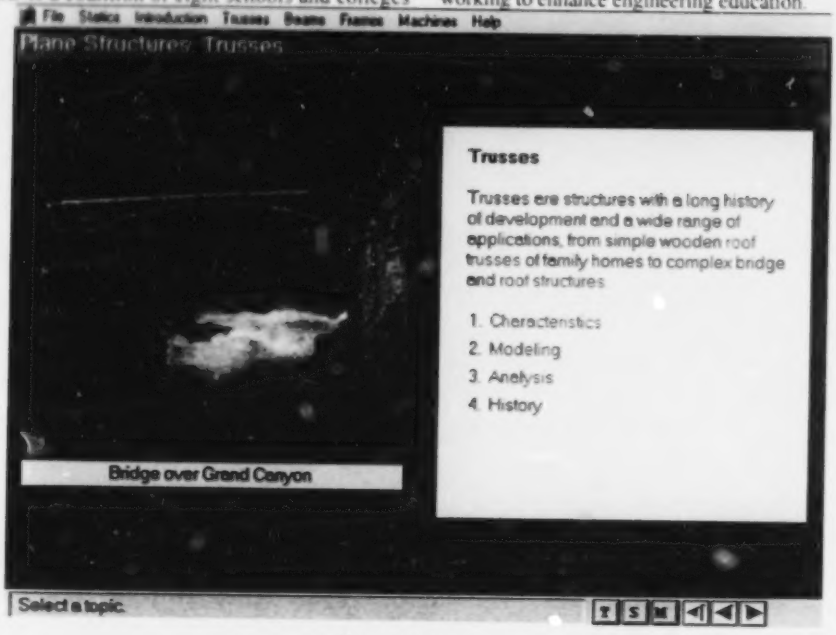
File Statics Introduction Trusses Beams Frames Machines Help
Plane Structures: Trusses
Bridge over Grand Canyon
Trusses
Trusses are structures with a long history of development and a wide range of applications, from simple wooden roof trusses of family homes to complex bridge and roof structures
1. Characteristics
2. Modeling
3. Analysis
4. History
Select a topic
T S M

Figure 2. Trusses

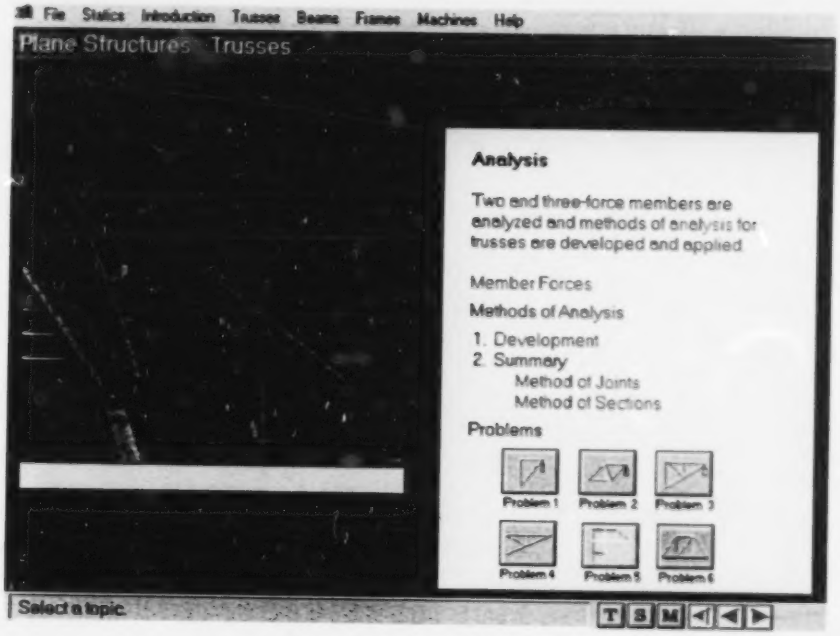

Figure 3. Analysis of Trusses

BEST COPY AVAILABLE

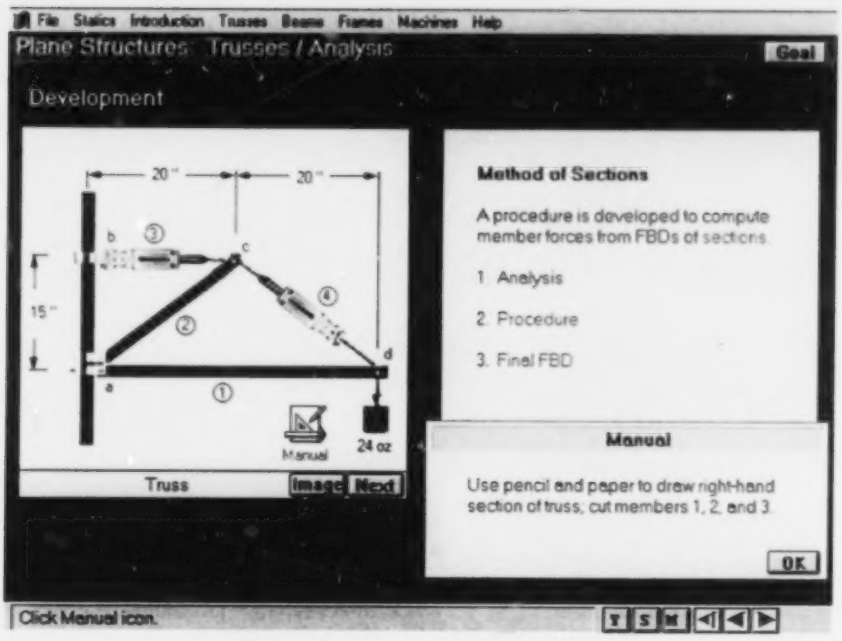

Figure 4. Development of Method of Sections

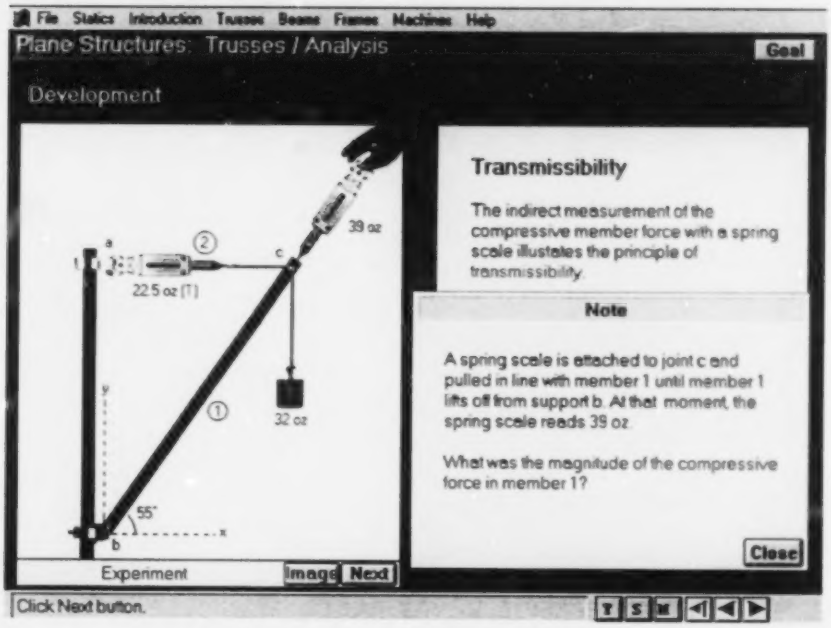
File Statics Introduction Trusses Beams Frames Machines Help
Plane Structures: Trusses / Analysis
Goal
Development
39 oz
22.5 oz (T)
32 oz
55°
Experiment
Image
Next
Transmissibility
The indirect measurement of the compressive member force with a spring scale illustates the principle of transmissibility.
Note
A spring scale is attached to joint c and pulled in line with member 1 until member 1 lifts off from support b. At that moment, the spring scale reads 39 oz.
What was the magnitude of the compressive force in member 1?
Close
Click Next button.

Figure 5. Measuring Compressive Forces

BEST COPY AVAILABLE

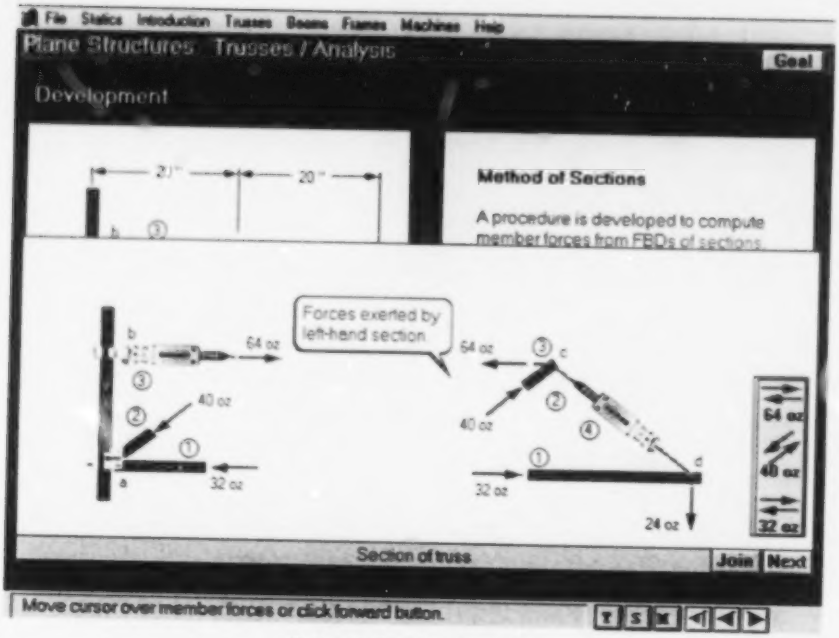

Figure 6. Results of Analysis

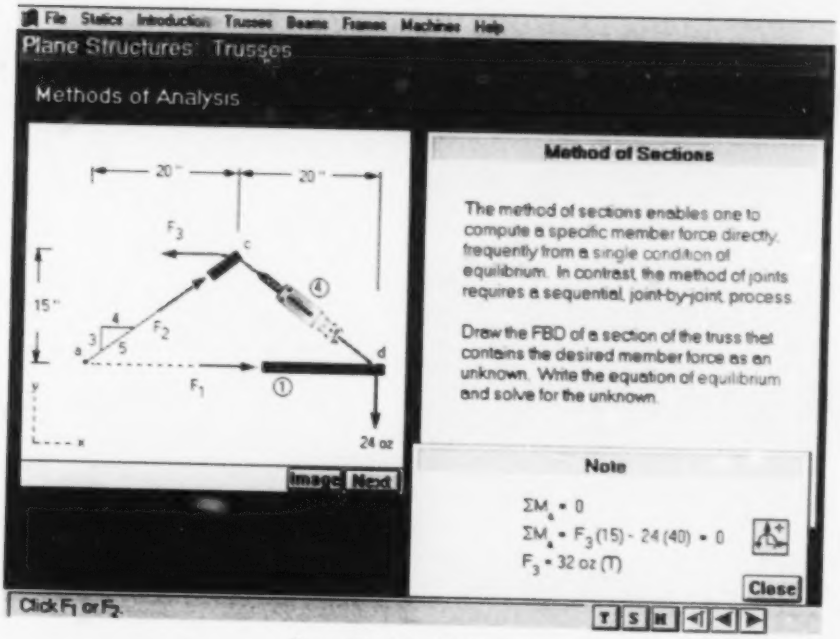
File Statics Introduction Trusses Beams Frames Machines Help
Plane Structures: Trusses
Methods of Analysis
Method of Sections
The method of sections enables one to compute a specific member force directly, frequently from a single condition of equilibrium. In contrast, the method of joints requires a sequential, joint-by-joint, process.
Draw the FBD of a section of the truss that contains the desired member force as an unknown. Write the equation of equilibrium and solve for the unknown.
Note
ΣM_a = 0
ΣM_a = F_3(15) - 24(40) = 0
F_3 = 32 oz (T)
Close
Image
Next
Click F1 or F2.

Figure 7. Method of Sections

BEST COPY AVAILABLE

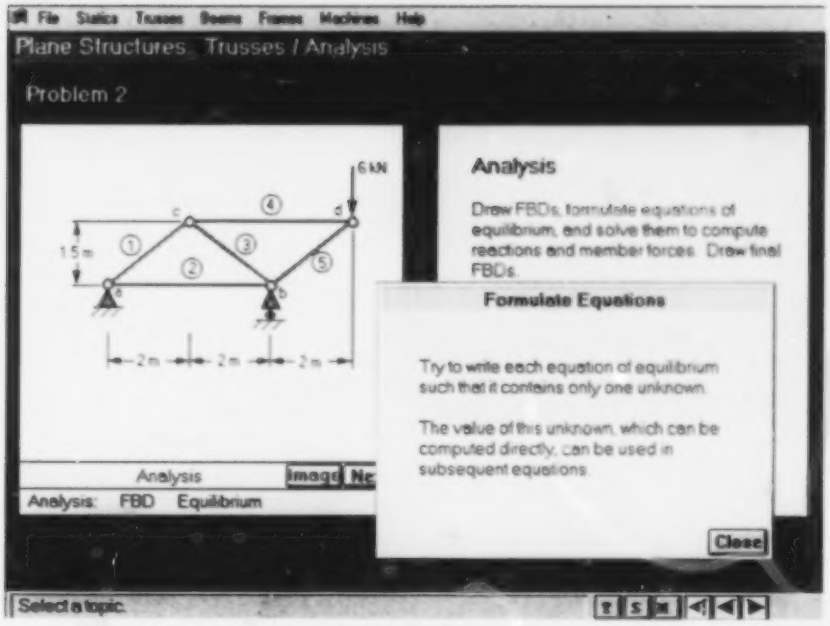
File Statics Trusses Beams Frames Machines Help
Plane Structures: Trusses / Analysis
Problem 2
6 kN
1.5 m
2 m
2 m
2 m
Analysis
Draw FBDs, formulate equations of equilibrium, and solve them to compute reactions and member forces. Draw final FBDs.
Formulate Equations
Try to write each equation of equilibrium such that it contains only one unknown.
The value of this unknown, which can be computed directly, can be used in subsequent equations.
Close
Analysis
Image
Next
Analysis: FBD Equilibrium
Select a topic.

Figure 8. Analysis of Simple Truss

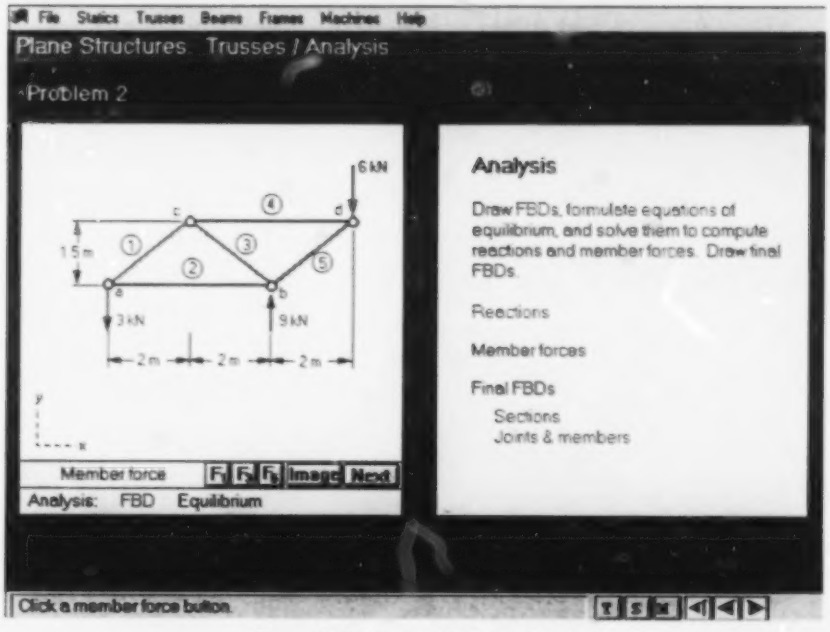

Figure 9. Selection of Member Force

BEST COPY AVAILABLE

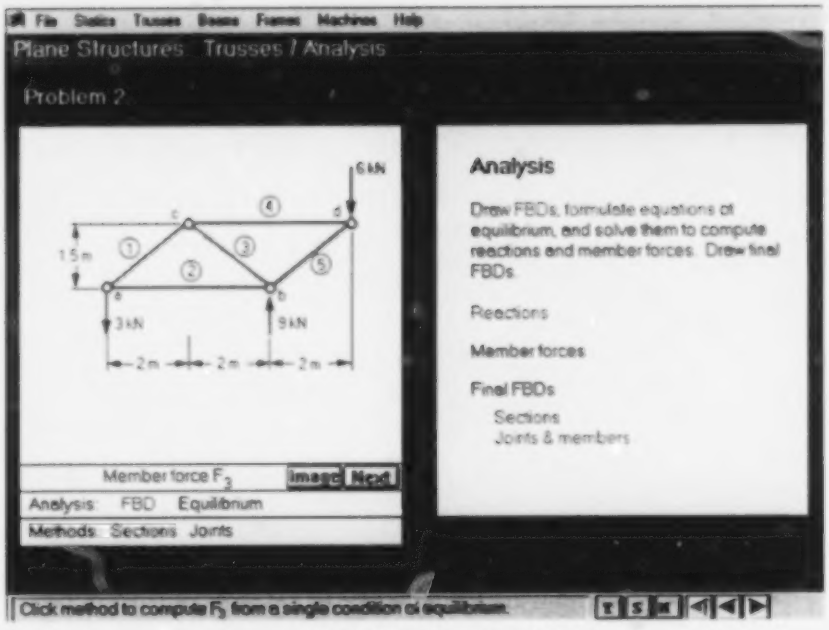

Figure 10. Selection of Analysis Method

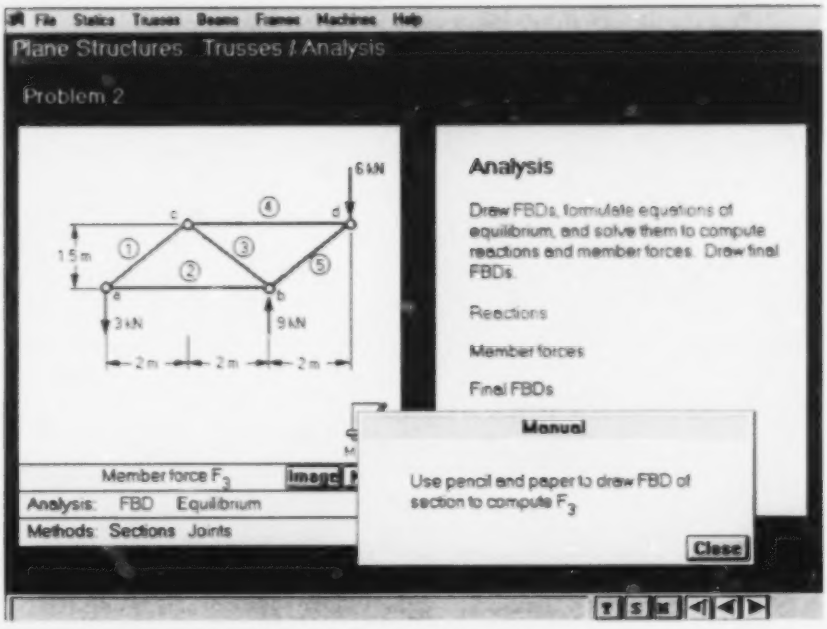

Figure 11. Pencil and Paper Activity

BEST COPY AVAILABLE

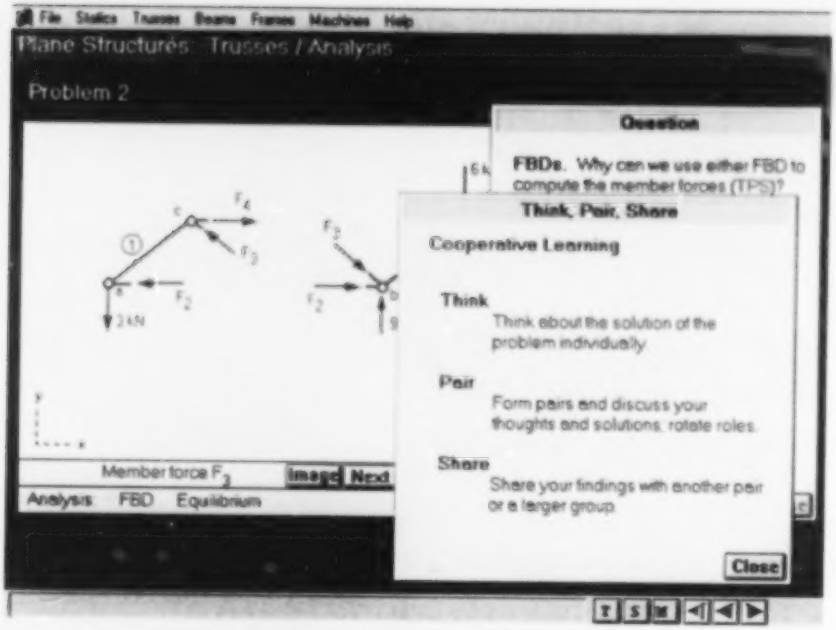
File Statics Trusses Beams Frames Machines Help
Plane Structures: Trusses / Analysis
Problem 2
Question
FBDs. Why can we use either FBD to compute the member forces (TPS)?
Think, Pair, Share
Cooperative Learning
Think
Think about the solution of the problem individually.
Pair
Form pairs and discuss your thoughts and solutions; rotate roles.
Share
Share your findings with another pair or a larger group.
Close
Member force F3
Image
Next
Analysis: FBD Equilibrium

Figure 12. Choice of Section

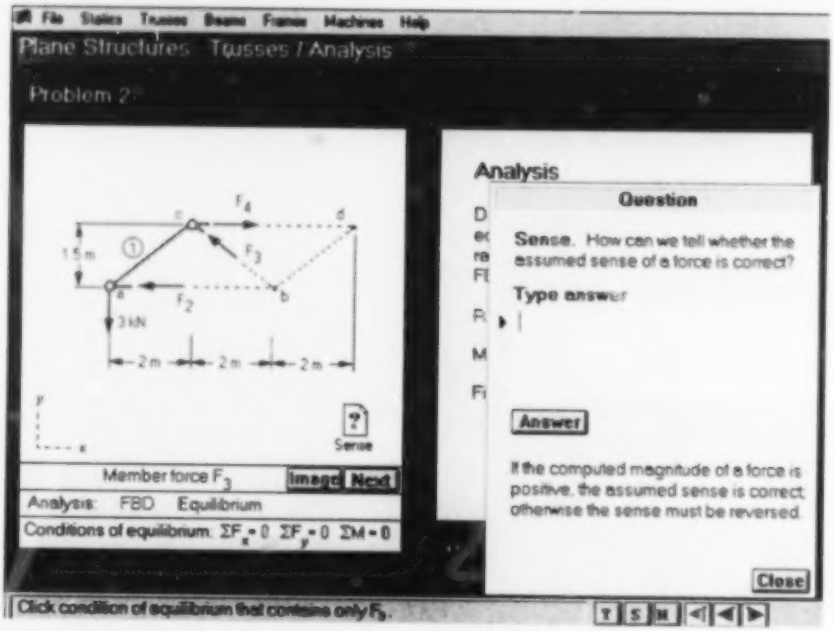
File Statics Trusses Beams Frames Machines Help
Plane Structures: Trusses / Analysis
Problem 2
Analysis
Question
Sense. How can we tell whether the assumed sense of a force is correct?
Type answer
Answer
If the computed magnitude of a force is positive, the assumed sense is correct; otherwise the sense must be reversed.
Close
Sense
Member force F3
Image
Next
Analysis: FBD Equilibrium
Conditions of equilibrium: ΣFx = 0 ΣFy = 0 ΣM = 0
Click condition of equilibrium that contains only F3.

Figure 13. Choice of Sense

BEST COPY AVAILABLE

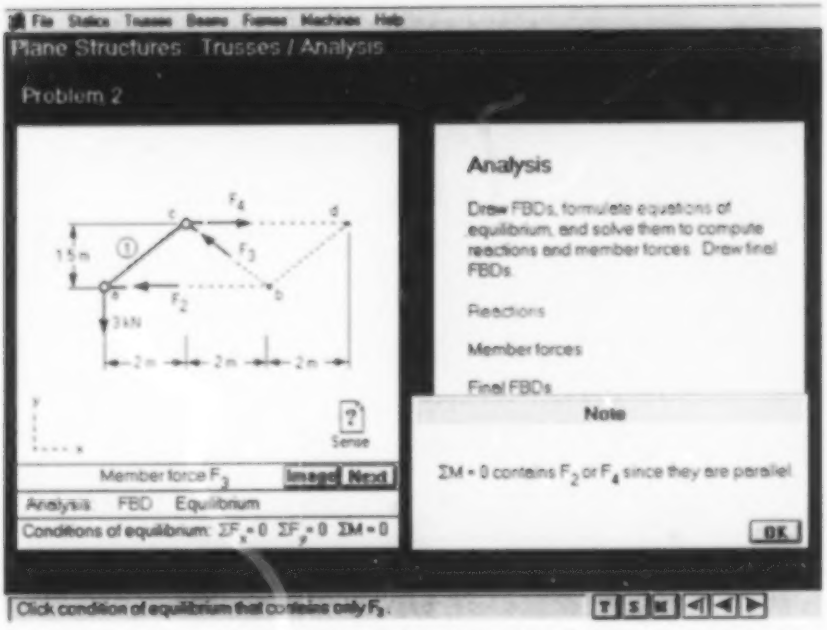
File Statics Trusses Beams Frames Machines Help
Plane Structures: Trusses / Analysis
Problem 2
Analysis
Draw FBDs, formulate equations of equilibrium, and solve them to compute reactions and member forces. Draw final FBDs.
Reactions
Member forces
Final FBDs
Note
ΣM = 0 contains F2 or F4 since they are parallel.
OK
Sense
Member force F3
Image
Next
Analysis: FBD Equilibrium
Conditions of equilibrium: ΣFx = 0 ΣFy = 0 ΣM = 0
Click condition of equilibrium that contains only F3.

Figure 14. Choice of Equilibrium Condition

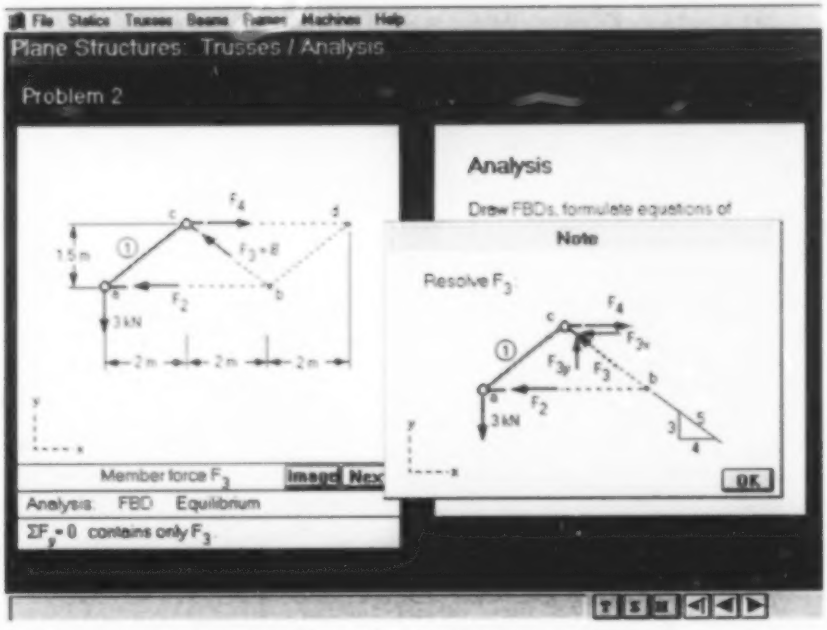

Figure 15. Error Message

BEST COPY AVAILABLE

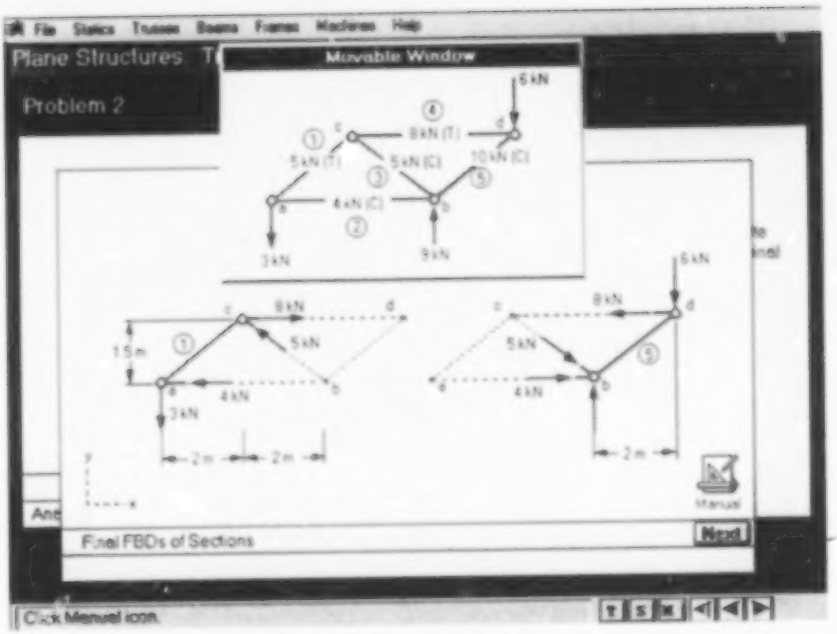

Figure 16. Final Free-Body Diagrams

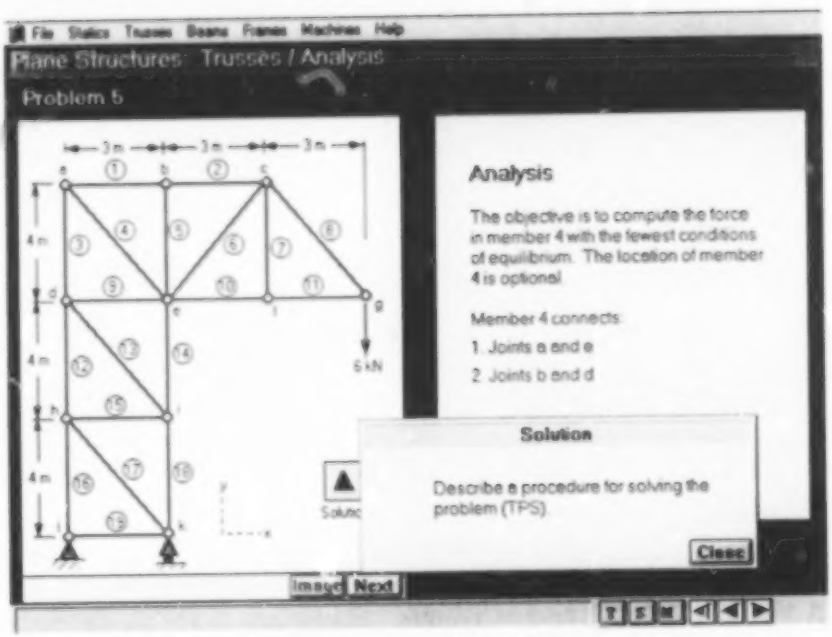
File Statics Trusses Beams Frames Machines Help
Plane Structures: Trusses / Analysis
Problem 5
3 m
4 m
6 kN
Analysis
The objective is to compute the force in member 4 with the fewest conditions of equilibrium. The location of member 4 is optional.
Member 4 connects
1. Joints a and e
2. Joints b and d
Solution
Describe a procedure for solving the problem (TPS).
Close
Next

Figure 17. Analysis of Complex Truss

BEST COPY AVAILABLE

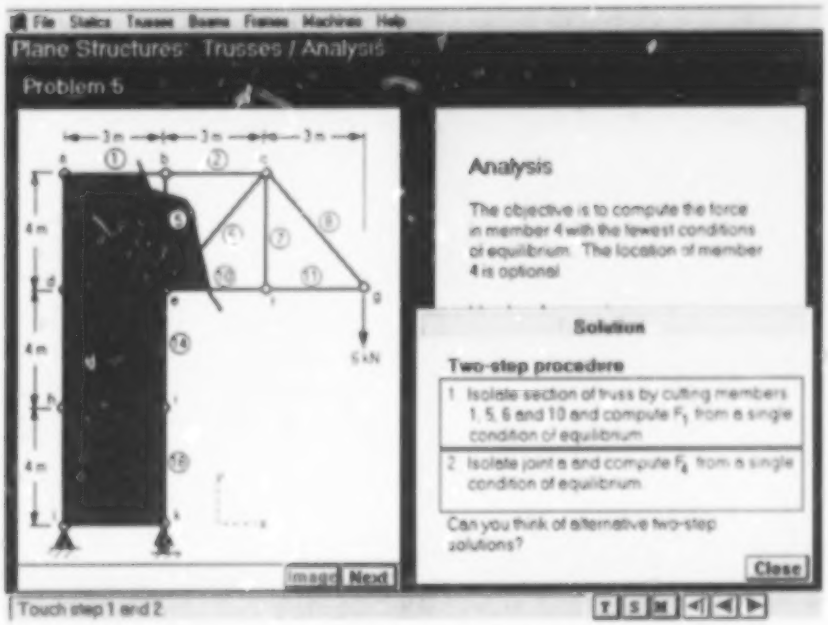
File Statics Trusses Beams Frames Machines Help
Plane Structures: Trusses / Analysis
Problem 5
3 m
3 m
3 m
4 m
4 m
4 m
5 kN
Analysis
The objective is to compute the force in member 4 with the fewest conditions of equilibrium. The location of member 4 is optional
Solution
Two-step procedure
1. Isolate section of truss by cutting members 1, 5, 6 and 10 and compute F_1 from a single condition of equilibrium
2. Isolate joint a and compute F_4 from a single condition of equilibrium
Can you think of alternative two-step solutions?
Close
Image
Next
Touch step 1 and 2.

Figure 18. Procedure for F_1

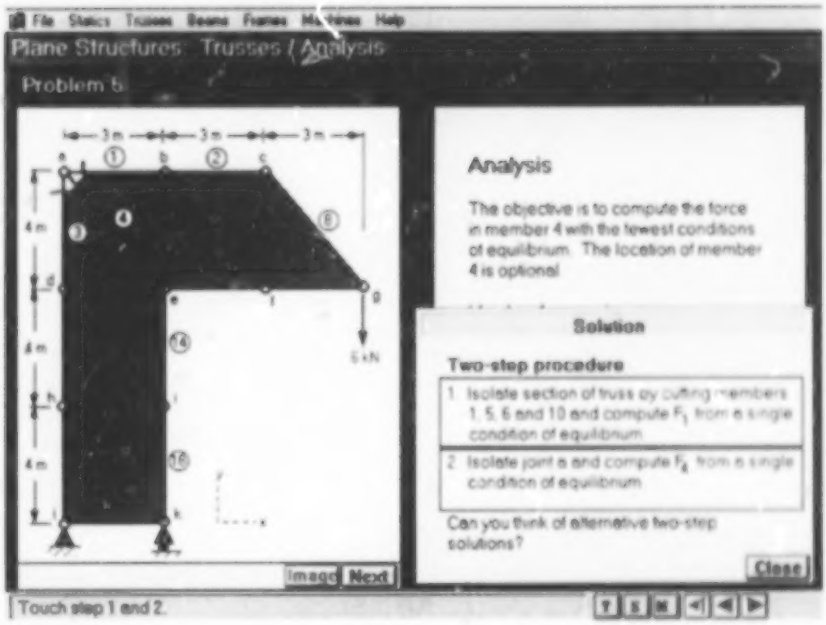
File Statics Trusses Beams Frames Machines Help
Plane Structures: Trusses / Analysis
Problem 5
3 m
3 m
3 m
4 m
4 m
4 m
5 kN
Analysis
The objective is to compute the force in member 4 with the fewest conditions of equilibrium. The location of member 4 is optional
Solution
Two-step procedure
1. Isolate section of truss by cutting members 1, 5, 6 and 10 and compute F_1 from a single condition of equilibrium
2. Isolate joint a and compute F_4 from a single condition of equilibrium
Can you think of alternative two-step solutions?
Close
Image
Next
Touch step 1 and 2.

Figure 19. Procedure for F_4

BEST COPY AVAILABLE

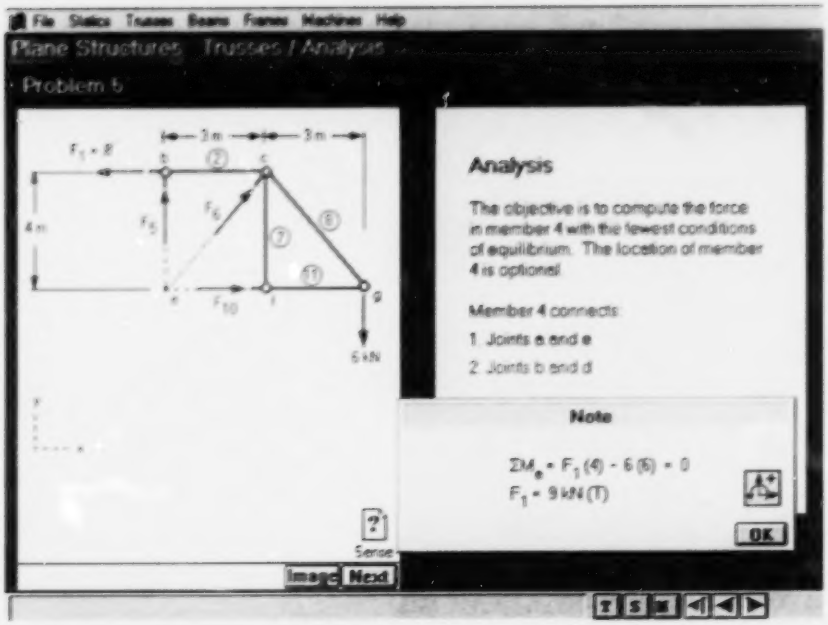

Figure 20. Computation of F_1

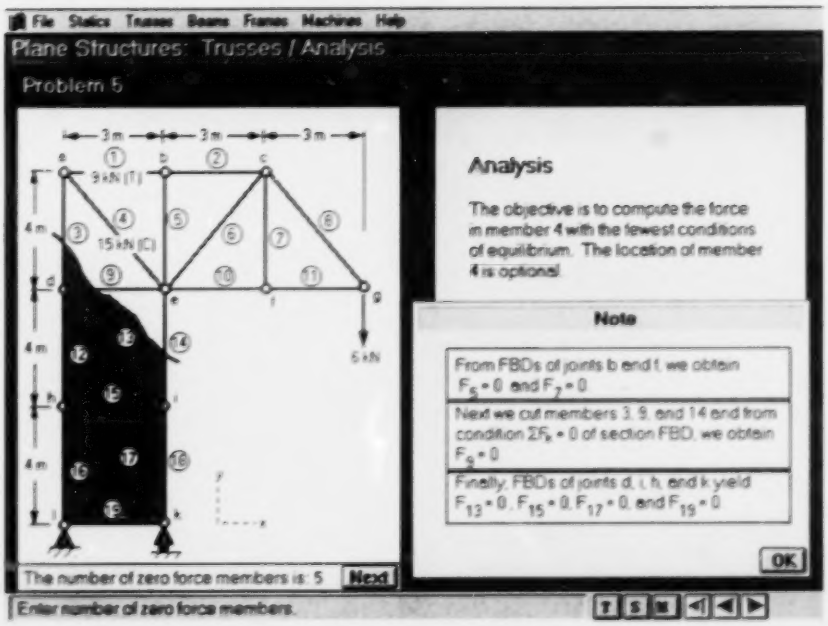
File Statics Trusses Beams Frames Machines Help
Plane Structures: Trusses / Analysis
Problem 5
3 m
3 m
3 m
9 kN (T)
15 kN (C)
4 m
4 m
4 m
6 kN
Analysis
The objective is to compute the force in member 4 with the fewest conditions of equilibrium. The location of member 4 is optional.
Note
From FBDs of joints b and f, we obtain $F_5 = 0$ and $F_7 = 0$
Next we cut members 3, 9, and 14 and from condition $\Sigma F_y = 0$ of section FBD, we obtain $F_9 = 0$
Finally, FBDs of joints d, i, h, and k yield $F_{13} = 0$, $F_{15} = 0$, $F_{17} = 0$, and $F_{19} = 0$
OK
The number of zero force members is: 5
Next
Enter number of zero force members.

Figure 21. Zero-Force Members

BEST COPY AVAILABLE

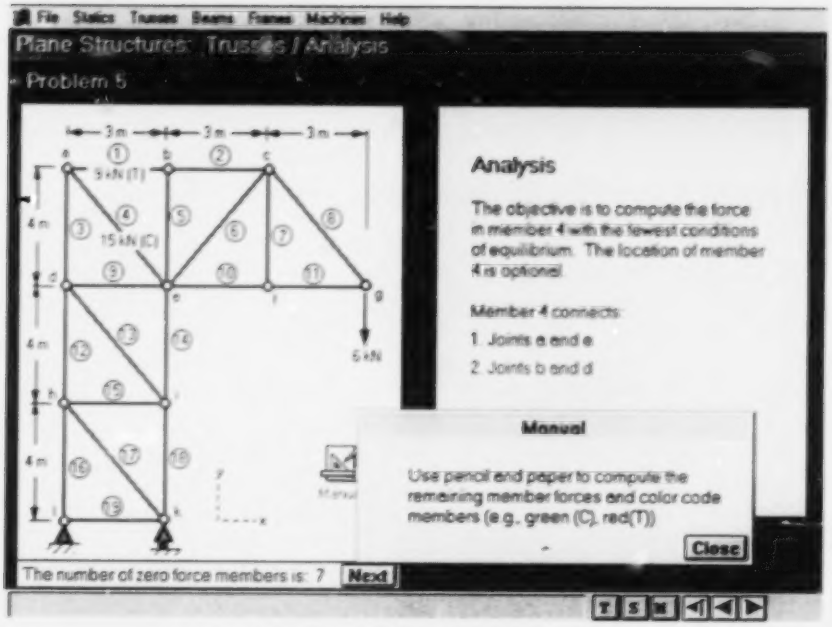
File Statics Trusses Beams Frames Machines Help
Plane Structures: Trusses / Analysis
Problem 5
3 m
3 m
3 m
4 m
4 m
4 m
9 kN (T)
15 kN (C)
6 kN
Analysis
The objective is to compute the force in member 4 with the fewest conditions of equilibrium. The location of member 4 is optional.
Member 4 connects:
1. Joints a and e
2. Joints b and d
Manual
Use pencil and paper to compute the remaining member forces and color code members (e.g., green (C), red(T))
Close
The number of zero force members is: 7
Next

Figure 22. Remaining Member Forces

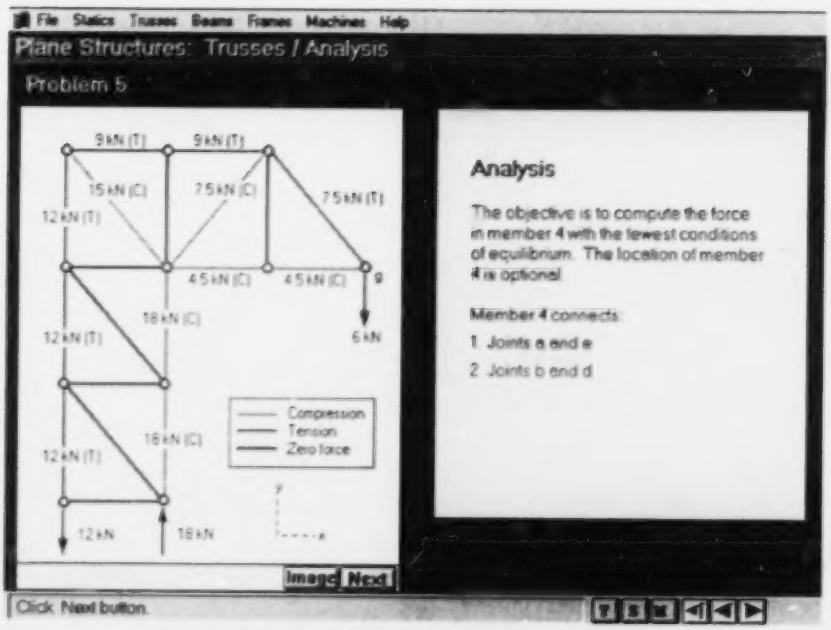

Figure 23. Color-Coded Member Forces

BEST COPY AVAILABLE